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Prosthetic Foot/Ankle Inversion & Eversion Enhancement

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Honors Project Final Paper: Prosthetic Ankle Inversion/Eversion Enhancement

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Abstract

This paper explains how our senior design team developed the final design for our prosthetic ankle inversion/eversion enhancement. First, we developed our problem statement along with the areas of research we focused on to do so. We then developed the customer requirements from our research and problem statement. After that, we describe our approach that included developing engineering requirements from our customer requirements that were incorporated into a preliminary design. The team performed risk analysis along with verification on the preliminary design to ensure the requirements were met. Finally, our final design is presented along with how the different components will work together.

Introduction

Our team wanted to focus on a problem that was relevant to current foot prosthetics on the market. The original problem statement was to “review existing designs for a prosthetic foot/ankle that provide power at the ankle joint for dorsiflexion/flexion and select one device to propose an enhancement that provides the capability of adding power across a simulated subtalar joint to provide inversion/eversion”. In order to understand the problem, our team performed research on (i) the clinical problem behind the need, (ii) other products/methods/technologies that are currently on the market, (iii) patents that were applicable to our design/problem, and (iv) related anatomy and physiology to the problem at hand.

Further research into the clinical problem revealed that the human foot is a complex biological structure. Like all structural aspects of the human body, different forces, ranges of motion, and actions can be achieved through the interactions within

this structure [1]. When attempting to imitate the natural human foot with a prosthesis, it can be a difficult process due to these intricacies. For example, inversion and eversion (Figure 1) in the human foot occurs at the subtalar joint located in the ankle [1]. Because the human ankle and foot are very complex, the normal gait utilizes eversion and inversion motions that are not created in isolation. The human ankle is composed of a multitude of different bones, not only from the foot but also come from the leg, including both the fibula and tibia. The bones work in tandem to create certain motions that are experienced within human gait. Without foot inversion and eversion movement incorporated into a prosthetic's design, the amputee is unable to have a physiologically accurate gait. Understanding the anatomy and physiology of how the foot and ankle work to create inversion and eversion gave us a clear idea of how components could function together in order to create the desired motions.

For this project, the team was concerned with motions at the ankle that provide eversion and inversion. Eversion allows the foot to move away from the center of the body, and the human ankle has the ability to evert 12° for its range of motion. Meanwhile, inversion is the motion that allows the ankle to move the foot towards the body, and the human ankle has the ability to invert 23° [1].

In addition to eversion and inversion, the ankle can create pronation and supination motions, as well as plantar flexion and dorsiflexion (Figure 1). Pronation is the act of the ankle moving the foot down and away from the body. Supination works in the opposite manner, moving the foot up and towards the body. Dorsiflexion works to move the foot upwards. Plantar flexion works to move the foot downwards. From these six different types of motions, supination and pronation are created by combinations of

inversion, eversion, dorsiflexion, and plantarflexion motions through normal human gait. In order to make sure that the project had best accommodated the user, the eversion and inversion movements must work alongside the dorsiflexion and flexion movements that already existed in the prosthetic chosen to modify.

To create these motions, ligaments play a crucial role in that they set limitations to constrain the bones so that they do not fall out of place. The ligaments naturally set areas of limitation so that the ankle does not overly invert or evert past what is natural in the human body. Another component of the human ankle that helps with the range of motions are joints. As noted above, the inversion and eversion motions are created by the subtalar joint in the ankle [1], which also allows for pronation and supination motions [2]. Therefore, the subtalar joint functions in all three anatomical planes [2], giving the ability of a wide range of motions. Our team realized that it was important to focus on this subtalar joint and its motion to be able to recreate the motion of inversion and eversion in the prosthetic. In addition, the subtalar joint is helpful for the body's ability to react to certain motions, such as pelvis or leg rotation or forces due to gait [2]. To design the modification, different loads would be required to be tested on the joint to ensure that the prosthetic does not weaken or break. In addition, due to the connectivity of the subtalar joint to other joints and ligaments that help to create the motions, the team's design was focused on recreating a subtalar joint because it starts and creates all of the motion for inversion and eversion.

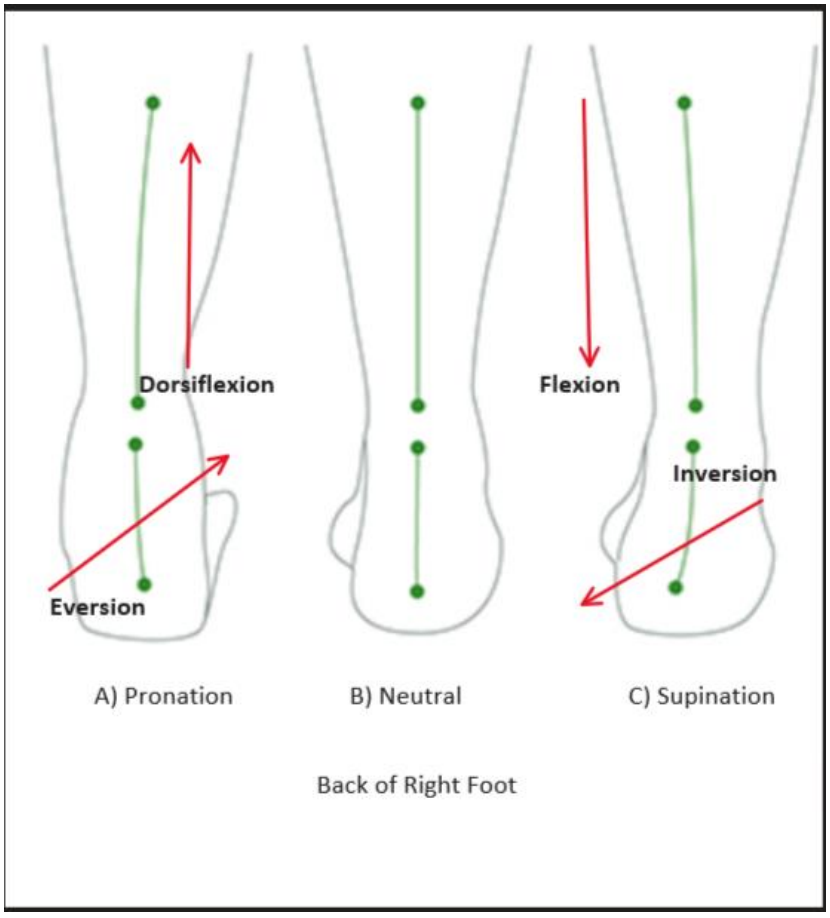


Figure 1. Pictured in (A) is pronation of the foot, arrows showing how dorsiflexion and eversion play a role in creating pronation are shown. Pictured in (B) is a neutral position of the foot for reference. Pictured in C) is supination of the foot, arrows showing how flexion and inversion play a role in creating supination are shown [3].

To limit our design to inversion and eversion, we researched the major companies that produce active foot prosthetics for dorsiflexion and flexion. Products, methods, and technologies currently on the market were examined in detail. The major manufacturers found were *Freedom Innovation*, *Ossur*, and *Ottobock*. With this research, we noted a major shortcoming with existing products is their inability to support the complex motion of foot inversion and eversion [4]. This lack of motion takes a toll on other joints of the lower extremity. Therefore, as excess energy is expended when walking and over time, the amputee could suffer from pathologies in the normal

ankle, knees, hips, and back due to unnatural movement patterns and weight distribution causing excessive forces and moments at the joints [5]. Looking at the different prosthetics that were currently on the market, we evaluated them by several factors. One of these factors included how easily we could attach our modification to the device, this is important because we wanted enough space to add the modification without interfering with the rest of the device. Another factor was what mechanism was providing the dorsiflexion/flexion power such as a microprocessor or hydraulics. This was important to consider because we wanted to ensure that our inversion/eversion mechanism would not interfere with the dorsiflexion/flexion mechanism already in place. Another important aspect was what activity level/person was the prosthetic designed for. This was important to us because we wanted to ensure that we would be choosing a prosthetic that was already capable of ambulation. The team reviewed these qualifications for each prosthetic chosen and after extensive evaluations by the team and a survey vote, we decided to build a new design around the medium-sized Kinnex Prosthetic. This prosthetic from Freedom Innovation was designed for individuals to use for ambulation. It has a large area on the superior portion of the foot that would be suitable for attachment of our modification. The Kinnex also has a microprocessor that will help integrate our design with greater ease in comparison to a hydraulic system [6].

A patent search was then performed to identify similar products or similar solutions to be able to get ideas for how to do our design and to assure that we don’t already copy a design that has been invented. Two concepts were identified that were similar to our problem of adding inversion/eversion to a lower limb prosthetic. Each device added inversion/eversion in a slightly different way. One device used a “C-

shaped” joint and the other device used a powered cable system [7] [8]. Unfortunately, no devices were found to modify an existing prosthetic that already had dorsiflexion/flexion to allow it to undergo inversion/eversion. In addition, no device patents were found that attempted to add power to a simulated subtalar joint. With this search, we were able to move forward with our design plans with assurance that we would be free to operate.

Our team reviewed and modified the problem statement in order to more accurately portray the problem our team would be solving. We modified the problem to specify that inversion/eversion would be the focus of the design to provide capability of walking on a flat surface, focusing on normal walking/gait. As noted above, we also modified the problem statement to define the product that would be altered. This product selection limited our customer to that of one that is a male that requires a medium-sized prosthetic foot/ankle. After these modifications were made, the resulting problem statement was reached, “Modify a medium-sized Kinnex (Freedom Innovations) prosthetic foot/ankle for a male, that currently has power at the ankle joint, for dorsiflexion/flexion so that it supplies active power through a degree of freedom that acts as a simulated subtalar joint, making the prosthetic capable of inversion/eversion while walking on a flat surface.”

Approach

We first developed customer requirements. In order to create adequate requirements, our team had to ensure that the customer would receive the product they desire. Therefore, the team put themselves in the shoes of the customer that would be receiving the product and considered what would be important to them. In doing so,

along with our team's research, our team developed detailed customer requirements (Table 1) and used them to create engineering requirements (Table 2) to assist in the creation of the final design that would meet the customer's needs.

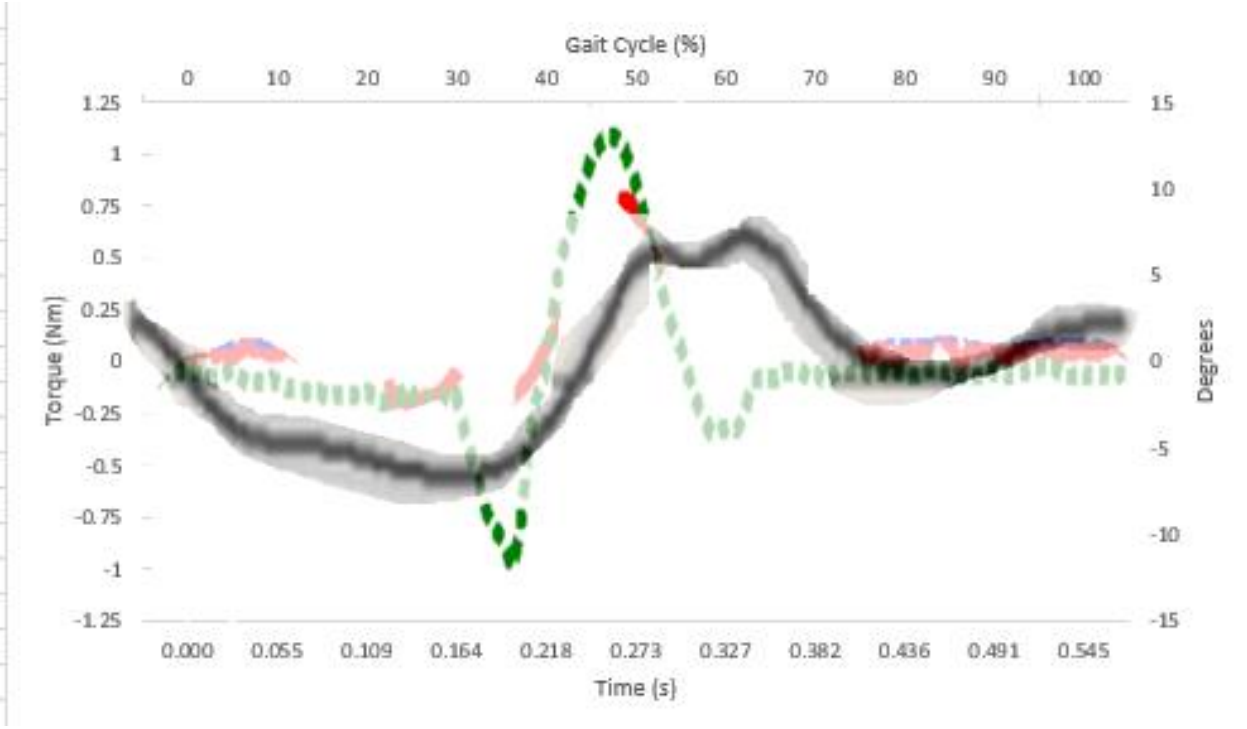
Table 1: Customer Requirements broken down into their Customer Requirement Number and their associated description.

Customer Requirement Number	Customer Requirement Description
1	Create a degree of freedom that assists the medium sized Kinnex prosthetic to approximately simulate natural human inversion/eversion physiology of a 20-40-year-old male.
2	Ensure the degree of freedom assists the medium sized Kinnex prosthetic to generate imitated forces that a 20-40-year-old male exhibits.

Table 2: Engineering Requirements

Engineering Requirement Number	Engineering Requirement Description
1	The Kinnex prosthetic foot/ankle shall be enhanced to add a degree of freedom to simulate a human subtalar joint in order to provide eversion and inversion of the foot.
2	The enhanced Kinnex prosthetic shall provide a maximum inversion of 8° ± 2° and should follow the profile within +/- 5% below in Figure 2.
3	The enhanced Kinnex prosthetic shall provide a maximum eversion of 6° ± 2 and should follow the profile within +/- 5% below in Figure 2.
4	The enhanced Kinnex prosthetic shall provide the torque for eversion within +/- 5% the profile of Figure 2.
5	The enhanced Kinnex prosthetic shall provide the torque for inversion within +/- 5% the profile of Figure 2.
6	Degree of freedom shall be added to a 26.7 cm sized Kinnex

	prosthetic foot the central line of the prosthetic (0.95 ± 0.3 cm from the edge of the foot), 0.15 ± 0.02 cm from the ground within the carbon fiber foot plate, and 8.83 ± .8 cm from the heel of the prosthetic.



Key:
Green Line = Torque (Nm)
Black Line = Degree of Inversion/Eversion

Figure 2: A graph of Ankle Inversion and Eversion over the gait cycle. The shaded region represents ±1 standard deviation. A second axis shows the time during the gait cycle it takes for a healthy 20-year-old male to complete. The black line represents a degree of inversion/eversion versus time and the gait cycle and the green line represents torque needed for inversion/eversion and the gait cycle. Negative values represent eversion. [8][9].

Utilizing the engineering requirements as a starting point, each member of the team researched and brought several preliminary designs to a brainstorming meeting. During the brainstorm meeting, each design concept was discussed and evaluated, and four final designs were chosen to examine further. These design concepts were the cable, ice cream scooper, block motor, and slide design (Appendix Figure 1A). In order

to determine the final preliminary design, the team ranked each of the four designs by several different categories. The ranking system went from (+) being the most likely to satisfy the category, (S) being somewhat likely to satisfy the category, and (-) being unlikely to satisfy the category. Some examples of these categories were Technology Readiness, Ability to Meet our Engineering Requirements, FDA Standards, Economic Factors, and Complexity and Feasibility. Further categories that were analyzed can be viewed in Appendix Figure A2. This evaluation resulted with the block and motor design being chosen. After this design was chosen, the team focused on the major components that would be necessary for this design and assessed what specifications were important for each component. The components that were initially identified were a motor for powering the system, an l-bracket to hold the motor, a system of gears to transfer the motion of the motor, and a pin to act as the axis of rotation for the prosthetic. Due to the selection of the final preliminary design and the assessment of the components needed, it was possible to make a rough sketch of the preliminary block motor design (Appendix Figure A3). This rough sketch and identified components gave us the results we needed to move forward in creating our final design.

To evaluate the design at several points within the process, our team created several Failure Mode and Effects Analyses (FMEAs) to assess product-associated risks. These FMEAs led to the creation of our final risk summary report that outlined the most important risks associated with our design. Finally, the team preformed several verifications in order to eliminate and reduce these risks as well as to verify that our final design concept would meet our engineering requirements and in turn satisfy our customer requirements.

Final Design

Starting with our preliminary drawings, we modified and downselected design traits by evaluating the risks. A major identified risk was the pinch point surrounding the active gears, which was resolved by adding a cover to the hindfoot that protected the gears in motion from external objects. Another risk we identified was the possibility of the forefoot becoming detached from the hindfoot due to an unsecure connection, which was mitigated in the final design when we selected the components for the Pin and Bearing. We chose materials that would be able to handle the forces required for this device. For assembly, the outer diameter of the Pin fits inside the central hole of the Bearing with tight clearances. These components would be assembled with a press fit. Other risks were identified and mitigated (Appendix Table A1).

As the team began to engineer the final design, we faced issues with contacting Freedom Innovations. We shifted the project to using SolidWorks to model a prosthetic foot that was based off of the Kinnex (Figure 3). The team planned on 3D-Printing the simulated Kinnex foot and modifying it to include inversion and eversion.

Figure 3: Kinnex Prosthetic [6] and 3D Rendering of Prosthetic

The engineering requirements defined by the team gave us important parameters for the final design process. The team took the parameters and implemented them into the final design with rigorous risk analysis to ensure our device wouldn't add unnecessary risk for the user. The mechanical aspects of the joint allow the inversion and eversion to occur at the location and with a range of motion that is specified in the engineering requirements. An example of a verification the team used to satisfy our engineering requirements was one to confirm the location of the joint. This requirement was verified by inspecting a Solidworks drawing to prove that the joint existed at the specified location (Appendix Tables A3 and A4). Each verification had a plan, which outlined what the verification was, a procedure that carried out the verification activities, and a summary report to provide data on whether the verification passed or not. Through these verifications, we were able to prove that the risks identified could be mitigated and that our engineering requirements could be achieved, giving us the confidence to move forward with our design. The selected motor has the ability to apply the necessary torques in the gait cycle from Figure 2. The final design (Figure 4) successfully resolved the clinical problem along with meeting the engineering requirements.

This device can be broken down into two groups based on the parts they are anchored to: the hindfoot (Item 2) and the forefoot (Item 3). The hindfoot is the fixed portion of the device that is attached to the amputee. The forefoot is the portion of the device that performs the inversion and eversion. These motions are made possible due to the pin joint that bridges the gap between the two. The Pin (Item 4) acts as a pivot and is the main component behind the simulated subtalar joint (Figure 5). Within the

simulated joint, the Pin (Item 4) is fixed to the hindfoot and the interior of the Bearing (Item 8). The exterior of the Bearing is fixed to the forefoot. The fixed relationship between the Pin and central hole of the Bearing causes the rotation of the device to stem from the bearing itself. The Half Gear (Part 10), Pin, and Bearing lie concentric to one another and this center is the axis of rotation. The system is powered by a DC motor (Item 6) that is fixed to the forefoot. This motor turns the Full Gear (Item 7) that interacts with the fixed Half Gear. These components work together to allow inversion and eversion on the simulated Kinnex prosthetic. The team was unable to validate this design due to school closures caused by COVID-19.

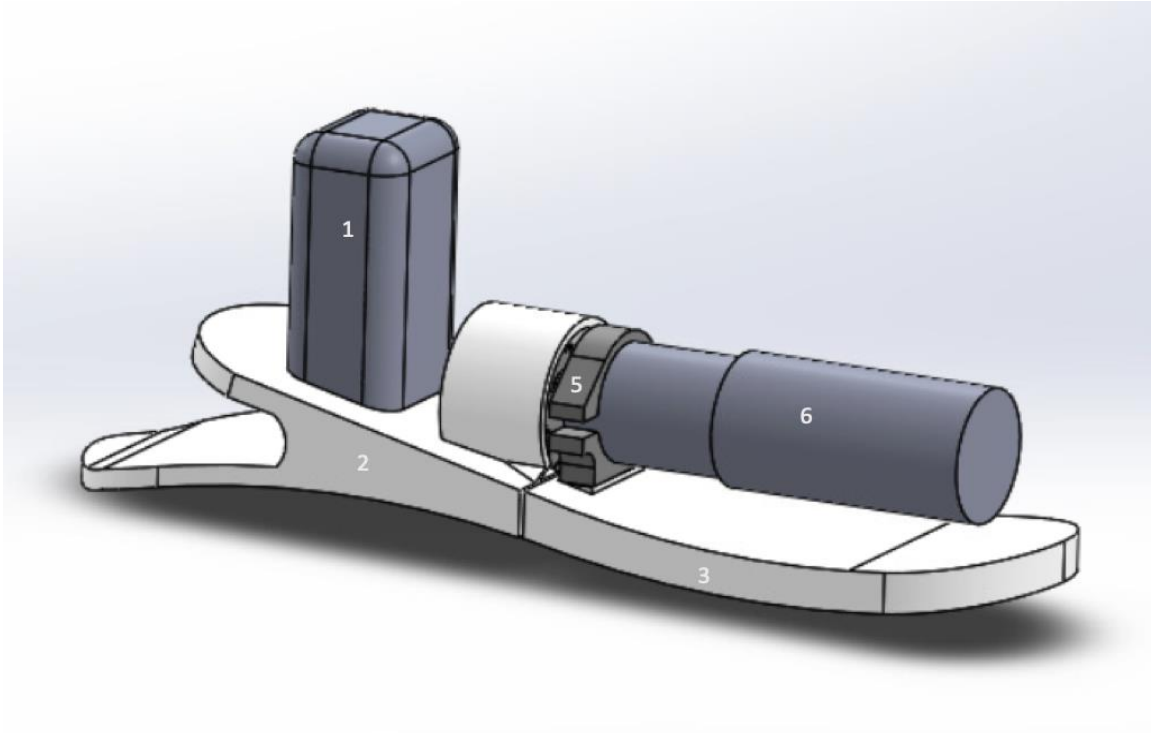


Figure 4: Final Design Trimetric View (Item 1 is the Ankle, Item 2 is the Hindfoot, Item 3 is the Forefoot, Item 5 is the Motor Bracket, Item 6 is the Motor)

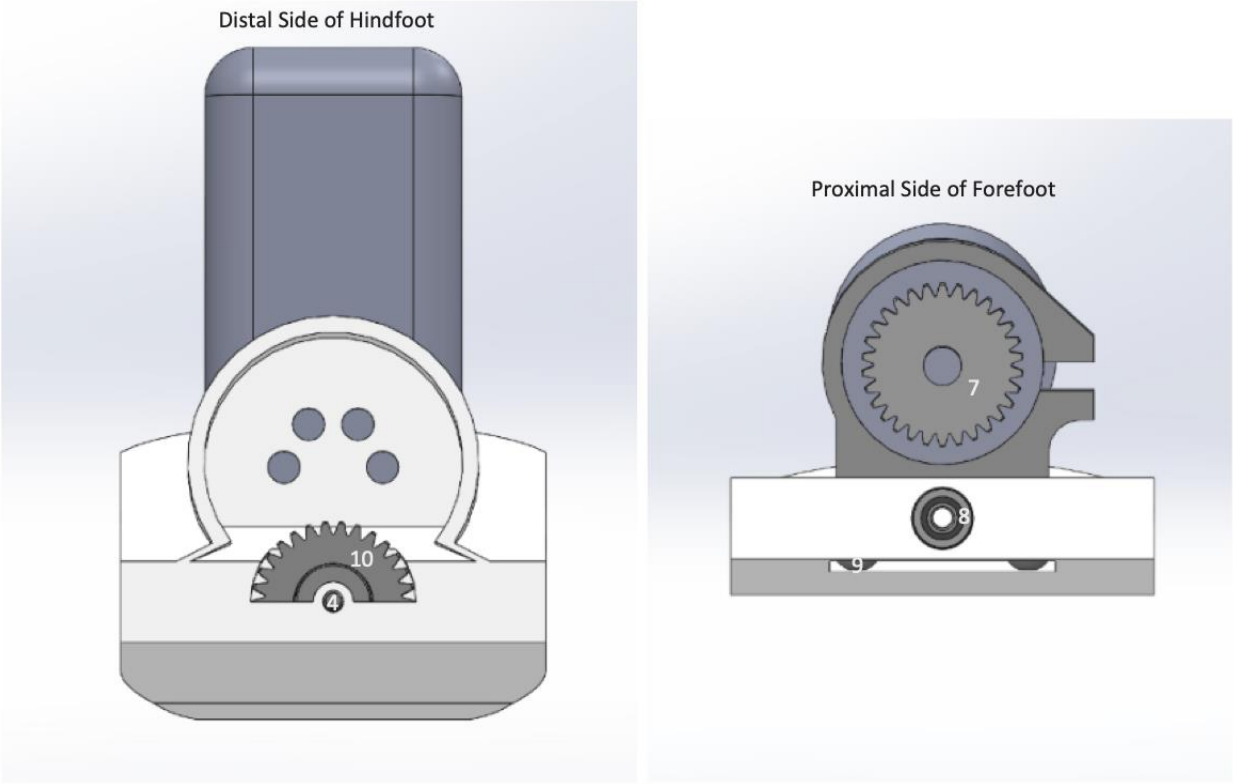


Figure 5: Split Subtalar View (Item 4 is the Pin, Item 7 is the Full Gear, Item 8 is the Bearing, Item 9 are the screws for the motor mount, Item 10 is the Half Gear)

Conclusion

The design enhancement could greatly improve the human gait if it was added to a device that already contained the ability to perform plantarflexion and dorsiflexion. This design was created with the range of motion and torques associated with inversion and eversion of the typical human foot in mind. These four motions working in unison would enable the amputee to walk with ease, have a decreased chance of falling, and reduce pathologies caused by prolonged time with irregular biomechanics. We evaluated that the design would also have no added risks incapable of mitigation. The benefits of having inversion and eversion outweigh the risks associated with the enhancement; therefore, this would be a good design to implement.

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Appendix

Table A1: Risk Summary Report Table outlining the name of the risks, a summary of the risk, the RPN value, how the risks were mitigated, and how the mitigation affected the RPN value. How the RPN value was calculated can be seen in Table A2. *Several verifications we performed assisted in mitigating the risks at hand. The Verification Plan Tables that outlined the verifications performed can be seen in Table A3 and A4.

Name of Risk	Summary of Risk	RPN	Mitigation	Mitigation RPN
The user falls	The user falls due to the addition of the inversion/eversion prosthetic modification.	12	Several verifications were put in place to avoid falling due to added inversion/eversion. These verifications are listed as follows, VER-EG2, VER-EG3, VER-EG4, and VER-EG5*. Future verification and validation activities will provide further assurance that this risk will be mitigated.	6
The user is injured during walking	The user is injured due to the addition of the inversion/eversion prosthetic modification during walking.	8	Several verifications were put in place to avoid injuries during walking due to added inversion/eversion. These verifications are listed as follows, VER-EG2, VER-EG3, VER-EG4, and VER-EG5*. Future verification and validation activities will provide further assurance that this risk will be mitigated.	8
Improper Inversion/Eversion	The prosthetic is not able to reach the proper inversion/eversion angle at the proper moments in the gait cycle.	8	Several verifications were put in place to avoid falling due to added inversion/eversion. These verifications are listed as follows, VER-EG2, VER-EG3, VER-EG4, and VER-EG5*. Future verification and validation activities will provide further assurance that this risk will be mitigated.	4
Injury due to handling the prosthetic	The user is injured by the prosthetic due to a reason other than walking. This could be due to handling the device while trying to take it on or off or interaction of the	8	Several verifications were put in place to avoid injury while handling the prosthetic. These verifications are listed as follows, VER-GHU1, VER-MM1, VER-M3, VER-M4, and VER-ALL2*. Future verification and validation activities will provide further	4

	prosthetic with different parts of the body.		assurance that this risk will be mitigated.	
The user receives an electric shock	The user is shocked due to the addition of the electronics needed for the prosthetic inversion/eversion modification.	8	Several verifications were put in place to avoid the possibility of the user being shocked. These verifications are listed as follows, VER-MM4, and VER-M3*. Future verification and validation activities will provide further assurance that this risk will be mitigated.	4
Components of the prosthetic break	The prosthetic breaks which leaves the user without a prosthetic. This could also lead to injury or falling if the prosthetic breaks while the user is walking.	8	Future verification and validation activities are needed to mitigate this risk.	8
Components of the prosthetic become misaligned/dislodged	Components of the prosthetic are misaligned/become dislodged which could lead to the user falling, the prosthetic breaking, or the user being injured.	8	Ensure that the assembly plan allows for the proper alignment and addition of each component. Future verification and validation activities will be needed to provide further assurance that this risk will be mitigated for the possible dislodging or misalignment of components after assembly.	8
Prosthetic does not have power for the inversion/eversion movement	The prosthetic does not receive the power necessary to perform inversion/eversion. This will make the prosthetic modification not useful to the user.	8	Future verification and validation activities are needed to mitigate this risk.	8
Prosthetic is stuck in inversion/eversion position	The prosthetic gets stuck in an inversion/eversion position. This could lead to improper alignment of the foot during the gait cycle which could lead to the user	8	Future verification and validation activities are needed to mitigate this risk.	8

	falling or injury to the user.			
Prosthetic Corrosion	The prosthetic corrodes away which could lead to further problems. These problems could include the prosthetic breaking, the user injuring themselves, and/or the user falling.	4	Verification, VER-ALL1*, was put into place to avoid the possibility of the prosthetic corroding. Future verification and validation activities will provide further assurance that this risk will be mitigated.	2
Prosthetic is too heavy	The prosthetic is too heavy causing irritation to the user and leading to possible long-term injuries of having to constantly carry excessive loads. This could also lead to the dorsiflexion, flexion, inversion, and eversion movements not working due to excessive loading.	4	Future verification and validation activities are needed to mitigate this risk.	4
Modification interrupts Flexion/Dorsiflexion Movement	The prosthetic interferes with the dorsiflexion/flexion movements. This could lead to improper alignment of the foot during the gait cycle which could lead to the user falling or injury to the user.	4	Future verification and validation activities are needed to mitigate this risk.	4

Table A2: Risk Priority Number Calculation Table. A value of one to three assuming least to greatest possibility for how severe, how likely it is to occur, and how detectable the risk is. These values are then multiplied together in the center and give levels of yellow to green for how low to high priority the risk is.

	Occurance				
Severity	1	2	3	Detectability	Level
3	9	18	27	3	1
3	6	12	18	2	2
3	3	6	9	1	3
2	6	12	18	3	4
2	4	8	12	2	6
2	2	4	6	1	8
1	3	6	9	3	9
1	2	4	6	2	12
1	1	2	3	1	18
					27

Table A3: Verification Plan for Engineering Requirements listing the engineering requirements, components of the design it is focusing on, the verification method, the resources needed for verification, the designated verification procedure number, and a description of the verification.

Engineering requirement	Component	Method	Resources	Verification Procedure Number	Verification Description
1	Assembly	Demonstration	SolidWorks Animation	VER-EG1	The SolidWorks assembly will demonstrate the added simulated subtalar joint.
2	Assembly	Demonstration	SolidWorks Animation	VER-EG2	The SolidWorks assembly will demonstrate the design is capable of achieving the maximum inversion angle of 8° ± 2°, as well as be able to demonstrate the angles of a normal gait cycle within ± 5% accuracy.
3	Assembly	Demonstration	SolidWorks Animation	VER-EG3	The SolidWorks assembly will demonstrate the design is capable of achieving the maximum eversion angle of 6° ± 2°, as well as be able to demonstrate the angles of a normal gait cycle within ± 5% accuracy.

4	Motor Gears	Analysis	Equation	VER-EG4	The motor and gear combination must be capable of demonstrating eversion torque according to a normal gait cycle within ± 5% accuracy.
5	Motor Gears	Analysis	Equation	VER-EG5	The motor and gear combination must be capable of demonstrating inversion torque according to a normal gait cycle within ± 5% accuracy.
6	Prosthetic forefoot and hindfoot	Inspection	SolidWorks Drawing	VER-EG6	The SolidWorks drawing will be checked for the simulated joint to be dimensionally in the correct position outlined in engineering requirement 6.

Table A4: Verification Plan for Engineering Requirements listing the engineering requirements, components of the design it is focusing on, the verification method, the resources needed for verification, the designated verification procedure number, and a description of the verification.

Risk Assessment Number	Component	Method	Resources	Verification Procedure Number	Verification Description
1.2-1.3, 1.5, 1.10	Gear Housing Unit	Inspection	SolidWorks Assembly	VER-GHU1	Add in a gear housing unit to ensure that the gears will be protected from debris and corrosion.
1.24-1.26, 1.33	Motor Mount	Inspection	Spec sheet for Motor Mount	VER-MM1	Inspection to prove that there is a dampening system, like a rubber strip inside the inner diameter of the motor mount to reduce the effects of vibration and possible shock to the patient.
1.27-1.30	Motor	Inspection	Spec sheet for Motor	VER-M3	Inspection to prove if the motor is UL certified.

			& Additional Motor Information		
1.27-1.31	All Components	Inspection	Spec Sheet for All Materials	VER-ALL1	Inspection to prove that all materials used in the design can withstand moisture corrosion
N/A	Motor Shaft	Demonstration	Warning Label	VER-M4	Demonstration to show that a Warning Label has been added to warn the user of possible pinch points with Motor Shaft.
N/A	All Components	Inspection	SolidWorks Assembly	VER-ALL2	Inspection to prove that there are no sharp edges on the prosthetic

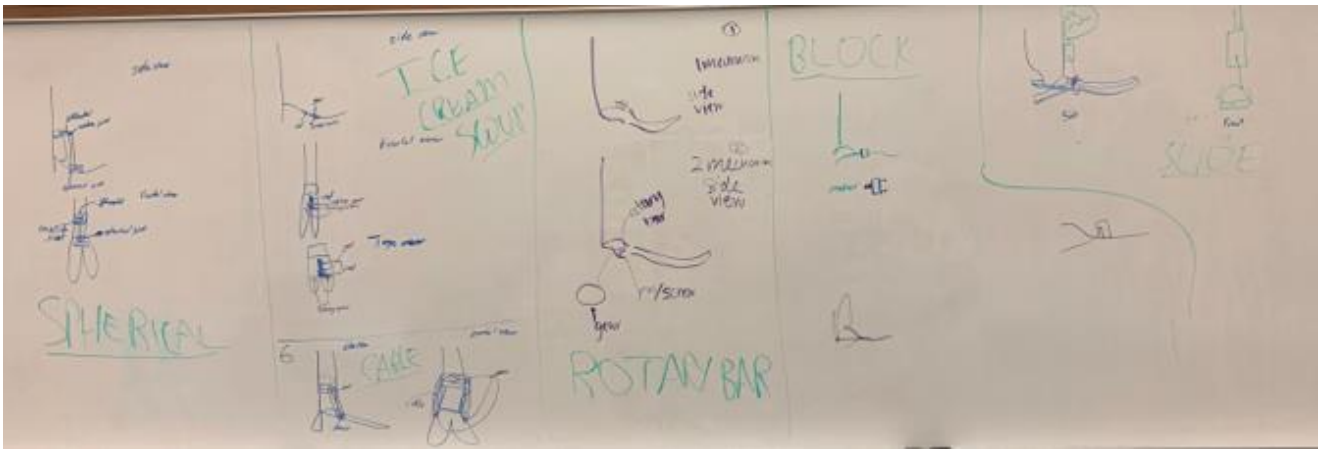


Figure A1: Team Brainstorming Design Concepts

Design Concepts: Concept Requirements:	Cable Design	Ice Cream Sccoper	Block Motor	Slide
The Kinnex prosthetic foot/ankle shall be enhanced to add a degree of freedom to simulate a human subtalar joint in order to provide eversion and inversion of the foot	(+)	(+)	(+)	(+)
The enhanced Kinnex prosthetic shall provide a maximum inversion of 8° ± 2° and should follow the profile below in Figure 1.	(+)	(+)	(+)	(+)
The enhanced Kinnex prosthetic shall provide a maximum eversion of 6° ± 2 and should follow the profile below in Figure 1.	(+)	(+)	(+)	(+)
Degree of freedom shall be added to a 26.7 cm. sized Kinnex prosthetic foot the central line of the prosthetic (0.95 ± 0.3 cm. from the edge of the foot), 0.15 ± 0.02 cm. from the ground within the carbon fiber foot plate, and 8.83 ± .8 cm. from the heel of the prosthetic.	S	S	S	S
The enhanced Kinnex prosthetic shall provide the torque for eversion according to the profile of Figure 1.	(-)	(+)	(+)	(+)
The enhanced Kinnex prosthetic shall provide the torque for inversion according to the profile of Figure 1.	(-)	(+)	(+)	(+)
Key Performance	S	(+)	(+)	S
Physical Characteristics	(-)	(+)	(+)	(+)
Technology Readiness	(+)	(+)	(+)	(+)
Solution Complexity and Feasibility	(-)	S	(+)	S
FDA Standards	(+)	(+)	(+)	(+)
Economic Factors	(+)	(+)	(+)	(+)
Ethics	(+)	(+)	(+)	(+)
Risks	S	S	S	S
Totals:				
(+)	7	11	12	10
S	3	3	2	4
(-)	4	0	0	0

Figure A2: Design Concepts Ranking System

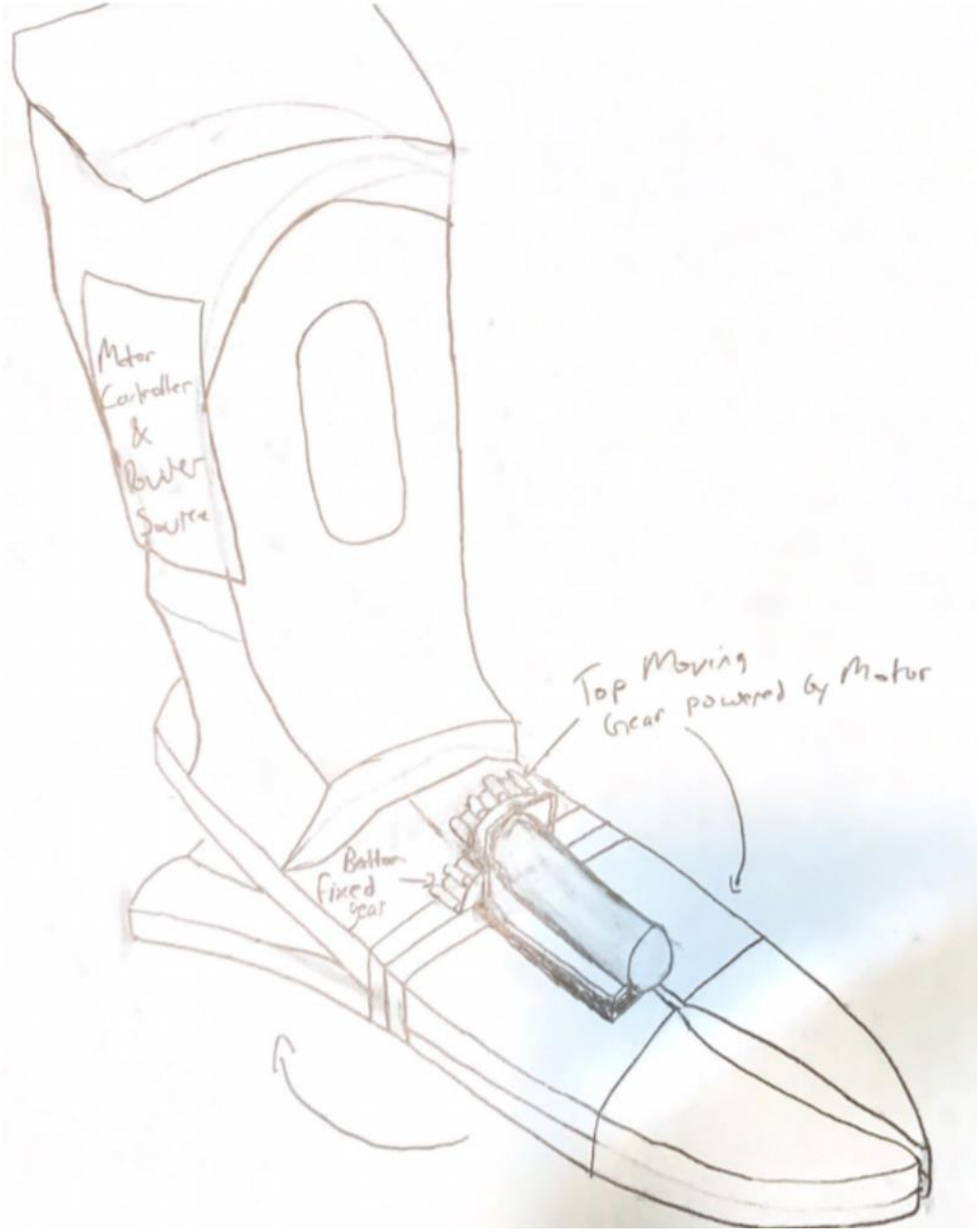


Figure A3: Preliminary Design

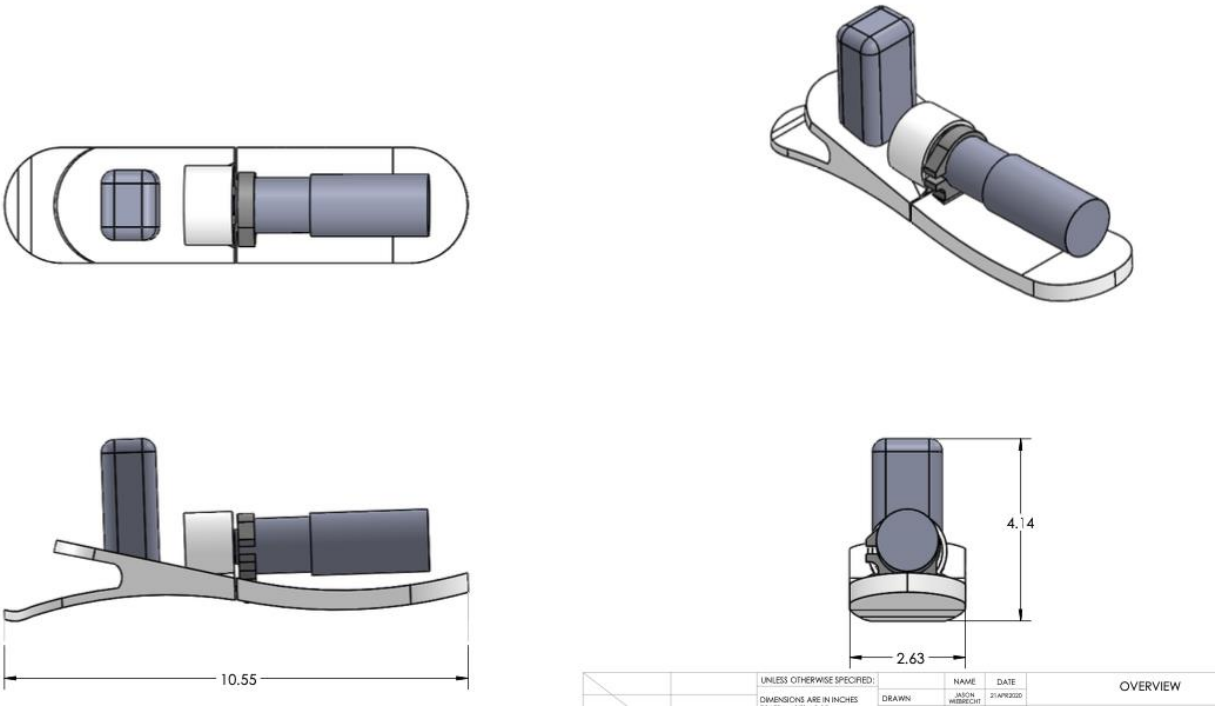
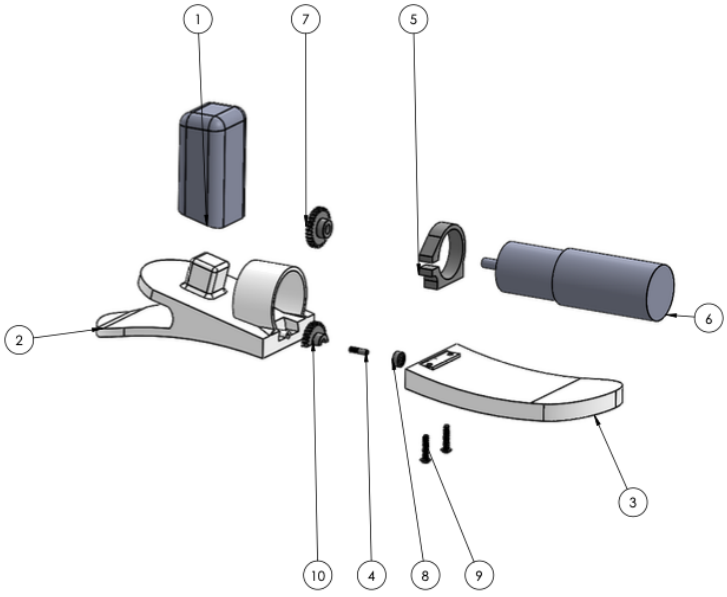


Figure A4: Final Design Overview



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIAL
1	C001-1	ANKLE	1	RAPTOR PLA
2	C002-1*	HINDFOOT	1	RAPTOR PLA
3	C002-1*	FOREFOOT	1	RAPTOR PLA
4	C003-1	HALF KNURLED PIN	1	1215 CARBON STEEL
5	C004-1	MOTOR CLAMP ASSEMBLY**	1	ALUMINUM
6	C005-1	DC MOTOR	1	N/A
7	C006-1	FULL GEAR	1	ACETAL PLASTIC
8	C008-1	BEARING	1	STEEL
9	C009-1	6-32 x 5/8" BUTTON HEAD SCREW	2	STAINLESS STEEL
10	C007-1	HALF GEAR	1	ACETAL PLASTIC

*PART C002-1IS THE ENTIRE FOOT. ITEM 2 IS HINDFOOT CONFIGURATION AND ITEM 3 IS FOREFOOT CONFIGURATION
**ASSEMBLY CONTAINS TIGHTENING SCREW AND DAMPENING RUBBER 0-RING THAT ARE NOT MODELED

Figure A5: Final Design Exploded

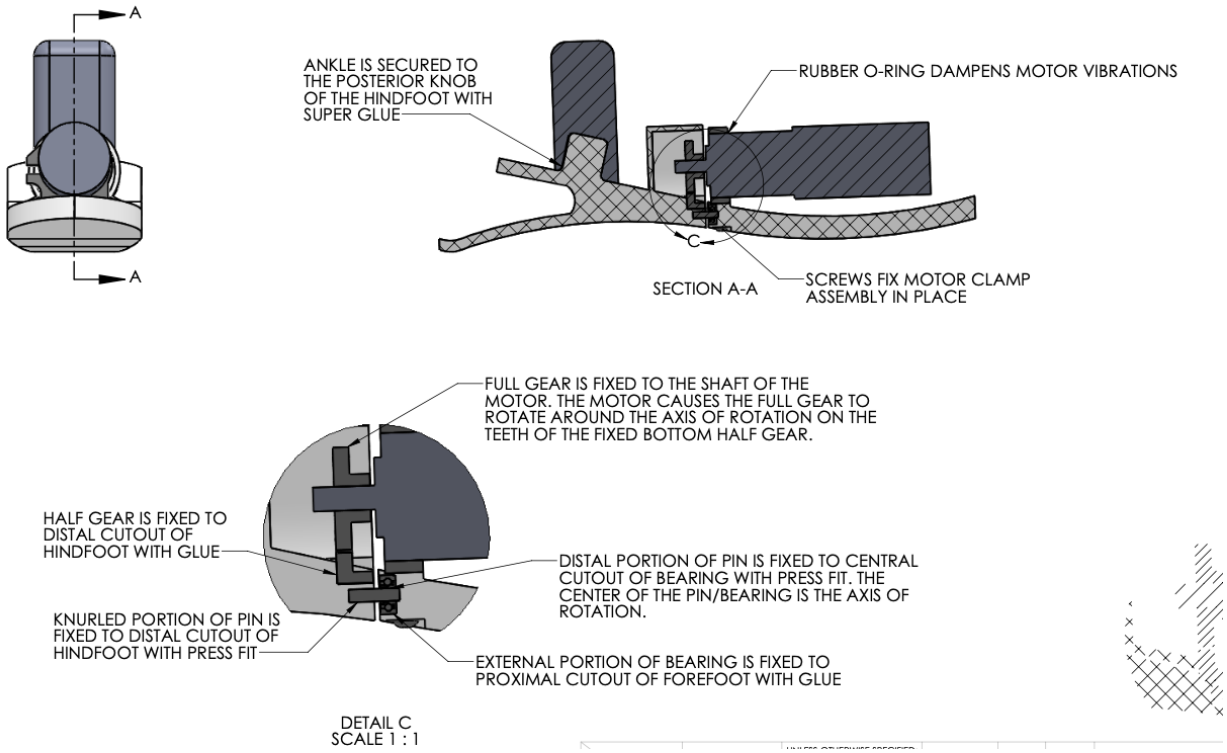


Figure A6: Critical Components